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Original Article

Comparing the Effectiveness of Two New CPR Training Methods in Korea: Medical Virtual Reality Simulation and Flipped Learning

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Abstract

Background: We compared the educational effects of two training methods that have gained momentum: medical virtual reality (medi-VR) simulation and flipped learning.

Methods: Firefighters (n=128; 116 men and 12 women; mean age=28 years) in training from the Emergency Educational Simulation Center of Korea National Fire Service Academy, Gongju-si, Korea, were randomly assigned to two groups: medi-VR simulation and flipped learning in 2022. The participants were trained to perform cardiopulmonary resuscitation (CPR) using medi-VR simulation and the flipped learning methods. CPR self-efficacy, knowledge, performance, class immersion, and class satisfaction were compared between the groups. To analyze educational effects, paired and independent *t*-tests were performed.

Results: The post-education scores for CPR performance knowledge and CPR performance were significantly higher in the medi-VR simulation group compared to the flipped learning counterparts (P<0.001). Moreover, despite the lack of a significant difference between the groups, post-education scores for self-efficacy, class immersion, and class satisfaction showed a positive effect on learning.

Conclusion: Medi-VR simulation can be utilized as effective educational intervention, while providing a new direction for teaching methods.

Keywords: Cardiopulmonary resuscitation; Class immersion; Flipped learning; Self-efficacy; Virtual reality simulation

Introduction

Over the past year, online education for firefighters has increased almost 86% compared to the 10-year average, attributable to the regional spread of the Coronavirus disease (1). However, prehospital critical care training still requires a significant amount of field practice. Therefore, online lectures for group training practice, such as cardiopulmonary resuscitation (CPR), which requires team activities and continuous contact, have limitations. CPR is an essential skill for resuscitating patients after cardiac arrest, especially for firefighters who are likely to witness cardiac arrests during disasters and accidents. Thus, there has been an increasing emphasis on the need for a new paradigm in training courses for national level firefighters.

Recently, medical virtual reality (medi-VR) simulation (2-3) and flipped learning (4-5) have drawn attention as new methods that can overcome the limitations of current educational methods in developing core competencies. Flipped learning is a learner-centered approach in which students study lecture materials as a pre-class step. During this pre-class time, students lead discussions, projects, and team activities to improve their in-depth learning of the content and its application. This method is more effective than the traditional method of CPR training (5), because it is student-centered and requires fewer resources (6).

Another teaching method, e-learning, which uses technologies such as VR, augmented reality, and mixed reality (MR), has rapidly emerged as an alternative method (7). E-learning can enhance the necessary competencies for adequate responses in the field and minimize trial and error due to inexperience. However, practice courses in fire drills for firefighting and disaster/accident situations using e-learning do not provide sufficient simulation-based education. In prehospital emergency care situations, the training requires skilled professional education.

To the best of our knowledge, most studies on this topic (3-6) have compared flipped learning and medi-VR simulation training with traditional methods to assess efficient CPR training. However, no study has compared the two: medi-VR simulation and flipped learning. To address this research gap, we compared the effects of medi-VR simulation and flipped learning for prehospital CPR emergency care training to proactively assess, identify, and confirm the most suitable teaching method for today's educational environment.

Materials and Methods

Study Design

Our study used a quasi-experimental design. Flow of the study is presented in Fig. 1.

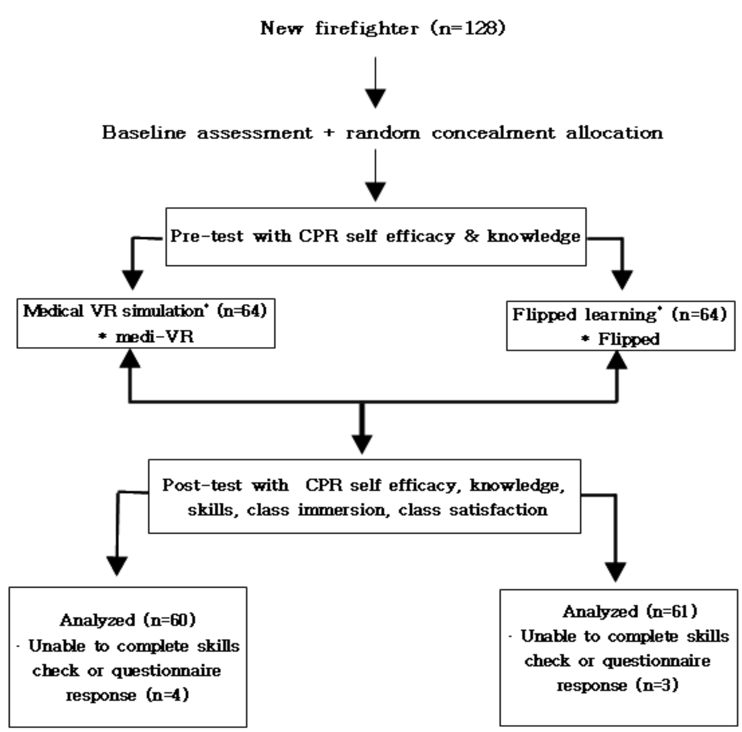

Fig. 1: Flow diagram of the study
CPR, cardiopulmonary resuscitation; VR, virtual reality

Participants

We calculated the number of participants we needed using G* Power software (G* Power 3.1.9.2, Heinrich-Heine-University, Düsseldorf, Germany). An independent *t*-test was conducted for statistical analysis; the number of samples was calculated by applying a sample number effect size of 0.50 (medium) with significance probability of 0.05. The power was 0.85, indicating that we needed 118 participants (8). Accordingly, we recruited 128 new firefighters from the Korea National Fire Academy, Sejong, Korea as participants, considering a 10% dropout rate, and randomly assigned them to two groups (64 in each group: medi-VR simulation and flipped learning).

Data Collection

The data collection period was on May 2022 in Emergency Educational Simulation Center of Korea National Fire Service Academy. Before we collected the data, we held an orientation session, describing the study purpose, gaining consent for the questionnaire, describing the participants' right to withdraw, the Personal Information Protection Act, the time needed to complete the questionnaire, and general procedures. We then evaluated CPR performance knowledge and self-efficacy before our education intervention. We evaluated post-education CPR self-efficacy, performance knowledge, performance practice, class immersion, and class satisfaction by dividing the participants into the medi-VR simulation and flipped learning group. There were 128 participants at the start of the experiment. Of these, seven people unable to participate in the post-test were excluded because of incomplete questions.

Ethical Considerations

The purpose and methods of the study were explained to the participants, and consent was obtained before data collection; the participants could withdraw from the study at any time with no disadvantages. Their personal information was protected and used for statistical analysis only. Furthermore, to ensure equal exposure to experience between the medi-VR simulation and flipped learning groups, post-completion, the flipped learning group had the opportunity to experience medi-VR simulation in the practice room for two weeks. This study was approved by the Korea National Fire Academy, Korea (2022-04).

Instruments

CPR performance

Concerning CPR performance, knowledge and practice scores are reflected equally (50% each) for a total score of 100 points; higher scores indicate higher competency in CPR.

CPR performance knowledge

Our study used the 2020 Korean Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care of the Korea Association of CPR as a reference to develop a tool for assessing CPR performance knowledge. We revised the questions according to the guidelines (9) and ended with 18 items, excluding two on breathing and pulse rates. The total score ranged from 0 to 18 points.

CPR performance practice

To evaluate CPR performance, we used an automated external defibrillator (AED). We assessed performance using 12 items finalized in the adult CPR and AED skills-testing checklist (9), shown in Table 1. A manikin (Resusci Anne W/Skill Guide [3110045]; Laerdal, Stavanger, Norway) was used to evaluate chest compression quality and increase reliability and validity.

CPR self-efficacy

We assessed CPR self-efficacy using the Korean version of the "Resuscitation self-efficacy scale" developed by Roh et al. (10). This consisted of 20 questions, each on a five-point scale, with higher scores indicating higher self-efficacy in CPR.

Table 1: Adult CPR and AED Skills Testing checklist

Category	*Evaluation items*	*Evaluator's instruction*
1. Verify scene safety	Scene safety and assessment of the scene	Scene is safe
2. Do personal protective equipment	Body substance isolation (wearing mask, gloves)	
3. Assess non-responsiveness through tap and shout	Check responsiveness (tap and shout -Call 119, -Ask for AED	Patient non-responsive
4. Assess breathing within 10 s	Don't look, listen and feel for breathing -Check respiration, -Don't pulse check, -Within 5~10/s	No breathing
5. Compressions -only CPR	Start compressions -Right-hand placement, -Right body position, -Chest compression, -"One, two, three.......thirty" (5 cm in depth, 100–120/min)	
6. Perform high-quality compressions	Compression (5 cm in depth) -Compression rate (100–120/min), -Hand placement (lower half of sternum), -Complete recoil after each compression	Skill-reporting manikin
7. Compression time (15'~17.99')	8. Hands-off time (~9.99) 9. Cycle of CPR (30 compressions)	
1 cycle 2 cycles 3 cycles	1 cycle 2 cycles 3 cycles 1 cycle 2 cycles 3 cycles	
10. Use AED; follow instructions from AED	Asking for help to bring an AED -Power on, -Attach pad, -Correctly attach pads (Lower left side of the chest, a few inches below the left armpit) -Inverted pad application, -Plug the pad connector cable into the AED, -AED rhythm analysis, -Clear for analysis , -Instruction for chest compressions during defibrillator charging , -Clear for analysis , -Clear to safely deliver a shock	AED on arrival (rescuer 2 enters, takes over compressions)
11. Resume compressions	Resume prompt chest compressions after shock delivery within 1~ 2 sec -Repeat 2 min of compression only CPR	
12. Algorithm of integration and prompt implementation	Execute the correct algorithm sequence -Done on time (3<min)	

Note: The adult CPR and AED skill-testing checklist is a tool adopted from the National Fertilizer Solutions Association and designed according to the 2020 Korean guidelines for CPR, reflecting the guidelines from the International Liaison Committee on Resuscitation.
CPR, cardiopulmonary resuscitation; AED: Automated external defibrillator

Class Immersion

We measured class immersion using the learning flow scale developed by Seok and Kang (11). This consisted of nine items, each rated on a five-point scale; higher scores indicated higher class immersion.

Class Satisfaction

We revised the questions developed by Yoo (12) to assess class satisfaction. For this, we created 26 items by adding two additional items to the original scale for our study. Each item was rated on a five-point scale, with higher scores indicating higher class satisfaction.

Study Procedure

Research Training

Before beginning our study, the research team received training in the development and use of the medi-VR education program at the university hospital's medi-VR simulation training center. Five research assistants received training in evaluation methods to ensure objective evaluation when using the AED performance practice assessment table.

Verification of Content Validity of the Learning Program

We consulted four professors at the National Fertilizer Solutions Association (NFSA) for advice on improving the content validity of the learning program.

Baseline Assessment

We conducted a homogeneity test using a questionnaire on height, weight, sex, age, and factors related to educational experience that may affect CPR emergency care. Among the dependent variables, we evaluated CPR performance, CPR knowledge, and CPR self-efficacy pre-education intervention to ensure homogeneity between the medi-VR simulation and flipped learning groups.

Experimental Intervention of medi-VR simulation and Flipped Learning

We conducted the education intervention with medi-VR simulation and flipped learning in pre-hospital cardiac arrest simulation training after consulting a professor, from the Emergency Medical Services in the Education and Training Department, on the experimental intervention procedure. The experimental procedure is described in the following section. The adult CPR and AED skills-testing checklist is a practice sheet for new firefighters designed by the National Fire Service Academy. We first conducted a pre-simulation practice session with five professors at the NFSA.

Medi-VR Simulation for Prehospital Cardiac Arrest Emergency Care

The procedure of medi-VR simulation is presented in Fig. 2.

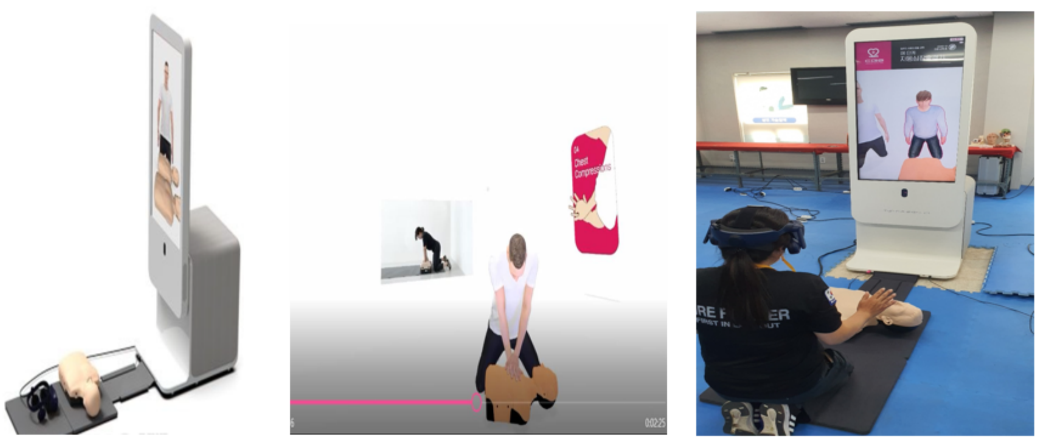

Fig. 2: Medical Virtual Reality simulator based on self-directed learning.

Pre-Class

For our learner-centered experiment, we used the existing commercial CPR medi-VR simulation program (VR-based CPR education system CBS 2.0 [VR simulator]; TETRA SIGNUM, Seoul, Korea).

In-Class

For our study, the in-class stage corresponded to the implementation stage of the Analysis, Design, Development, Implementation, and Evaluation model. The class was carried out sequentially by learning theoretical background, simulating practice (in the order of the medi-VR simulation program), and conducting individual or collaborative team activities. Team practice was conducted by dividing the students into six groups, with 10 participants in each. Emergency care practice was conducted for 45 minutes, including a 10 minute break. Additionally, in the middle of the individual practice session, the lecturer provided participants with immediate feedback through medi-VR simulation for any incorrect action.

Post-Class

In the post-class stage, we evaluated the pre-stage activities. The participants were divided into teams to perform the simulation practice. We set aside a total of 60 minutes for individual CPR performance evaluation. We conducted a survey to assess post-education CPR knowledge, performance practice, self-efficacy, class immersion, and class satisfaction.

Flipped Learning for Prehospital Cardiac Arrest Emergency Care

The flipped learning course was conducted as shown in Fig. 3.

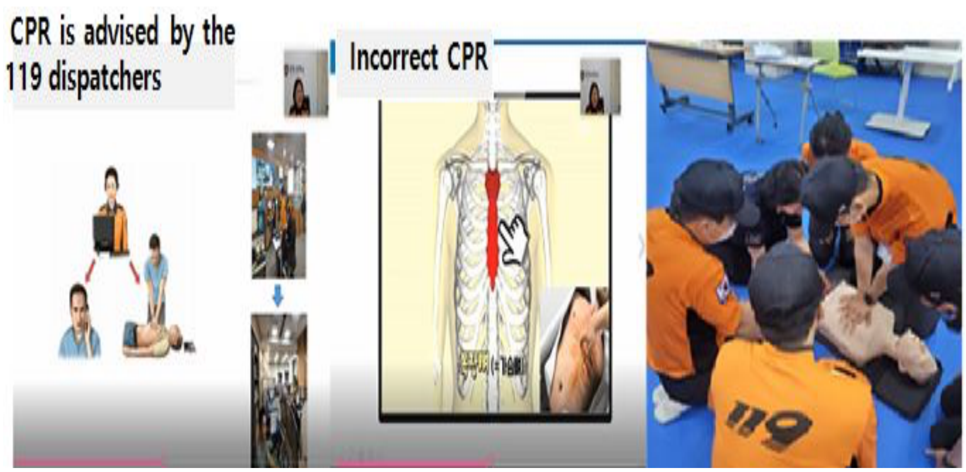

Fig. 3: Flipped learning course

Pre-Class

The pre-class stage was designed based on the teaching-learning model for flipped learning by the NFSA. We selected 61 participants as the flipped learning group; CPR theory and AED use were combined into a 10-minute video. Using the KakaoTalk (Kakao Corp., Seoul, Korea) group chat room, we uploaded the videos and learning materials (PowerPoint materials and promotional video) to the online learning space titled "NFSA Flipped Learning," which was exclusive to the participants.

In-Class

We conducted the emergency care practice by dividing the participants into six groups (n=10 per group). During this practice, they were given immediate feedback for incorrect actions. CPR performance was learned through team discussions. Through this, participants could have direct experience in performing CPR emergency care and familiarize themselves with the steps they had previously only learned in the online class at the pre-class stage.

Post-Class

In the post-class stage, we evaluated individual CPR performance. The participants were divided into two groups. We then conducted a survey to assess post-education CPR performance knowledge, performance practice, self-efficacy, class immersion, and class satisfaction.

Statistical Analysis

We used the SPSS Statistics 28.0 (IBM Co., Armonk, NY, USA) program to analyze participant general demographic characteristics and CPR-related variables using frequencies, percentages, means, and standard deviations. We used the Kolmogorov-Smirnov test to assess normality, the chi-square test ($\chi 2$) and independent *t*-test to perform homogeneity tests between groups, a paired *t*-test to analyze the difference between pre- and post-education in the medi-VR simulation and flipped learning groups, and an independent *t*-test to analyze the post-education difference between the groups. We set the significance level at a two-tailed *P*-value of 0.05.

Results

There were no significant differences between the medi-VR simulation and flipped learning groups concerning the demographic characteristics or CPR-related variables, confirming the homogeneity of the two groups (Table 2).

Table 2: Homogeneity test of participant demographics and CPR-related variables

Characteristics		*Group*				*Total*		*χ² (P)*
		Medi-virtual reality simulation (n=60)		Flipped learning (n=61)				
		n	%	n	%	n	%	
Sex	Male	54	90.0	55	90.2	109	90.1	0.001
	Female	6	10.0	6	9.8	12	9.9	(0.976)
Employment type	Paramedic	9	15.0	3	4.9	12	9.9	3.442
	Firefighter	51	85.0	58	95.1	109	90.1	(0.064)
License related to emergency care	Emergency Medical Technician-Paramedic	2	3.3	4	6.6	6	5.0	3.396 (0.170)
	Nurse	10	16.7	4	6.6	14	11.6	
	No license	48	80.0	53	86.9	101	83.5	
Education level	High school or below	20	33.3	19	31.1	39	32.2	0.218 (0.897)
	College	8	13.3	7	11.5	15	12.4	
	University	32	53.3	35	57.4	67	55.4	
Experience in simulation-based education	Yes	26	43.3	24	39.3	50	41.3	0.199
	No	34	56.7	37	60.7	71	58.7	(0.656)
		Mean	SD	Mean	SD	*t*		*P*
Age (years)		28.37	3.151	27.80	3.807	-0.886		0.377
Height (cm)		173.72	6.034	174.51	6.071	0.719		0.473
Weight (kg)		70.38	11.272	72.49	9.307	1.123		0.264
Number of simulation-based education (times a year)		2.50	2.064	3.17	2.959	0.930		0.357
Time of education (hours)		3.73	3.080	4.88	4.485	1.059		0.295
Performance knowledge (pre-survey, scores)		10.52	3.202	10.57	3.003	0.101		0.920
Self-efficacy (pre-survey, scores)		3.45	0.750	3.34	0.666	-0.846		0.399

Tested by chi-square or independent *t*-test
CPR; cardiopulmonary resuscitation, SD; standard deviation

In the medi-VR simulation and flipped learning groups (Table 3), the mean scores for CPR performance knowledge and self-efficacy were significantly higher post-education than pre-education ($P<0.001$).

Table 3: Difference in CPR performance knowledge and self-efficacy before and after medi-virtual reality simulation and flipped learning.

	Variables	*Pre-education*		*Post-education*		*t*	*P*
		Mean	SD	Mean	SD		
Medi-virtual reality simulation (n=60)	CPR performance knowledge	10.52	3.20	15.33	1.57	-10.886	<0.001***
	Self-efficacy	3.45	0.75	4.42	0.52	-11.125	<0.001***
Flipped learning (n=61)	CPR performance knowledge	10.57	3.00	12.33	1.54	-4.759	<0.001***
	Self-efficacy	3.34	0.67	4.25	0.54	-11.763	<0.001***

***P<0.001; tested by paired t-test
CPR, cardiopulmonary resuscitation; SD, standard deviation

As shown in Table 4, CPR performance knowledge was significantly higher in the medi-VR simulation group than that in the flipped learning group post-education (P<0.001). However, there was no significant difference in CPR self-efficacy between the groups post-education (P=0.082). Overall, CPR performance was significantly higher in the medi-VR simulation group than that in the flipped learning group (P<0.001). In prehospital cardiac arrest emergency care, the scores for CPR class immersion and class satisfaction were higher in the medi-VR simulation group than in the flipped learning group, but the differences were not significant (P>0.05).

Table 4: Difference in CPR self-efficacy, performance knowledge, performance practice, and performance between the medi-virtual reality simulation and flipped learning group

Variables	*Medi-virtual reality simulation (n=60)*		*Flipped learning (n=61)*		*t*	*P*
	Mean	SD	Mean	SD		
Performance knowledge	15.33	1.57	12.33	1.54	-10.648	<0.001***
Self-efficacy	4.42	0.52	4.25	0.54	-1.752	0.082
Performance knowledge (50 points)	43.33	3.92	35.82	3.84	-10.648	<0.001***
Performance practice (50 points)	42.58	4.68	41.12	4.25	-1.789	0.076
Performance (100 points)	85.91	6.93	76.94	6.08	-7.569	<0.001***
Class immersion	4.31	0.50	4.23	0.58	-0.908	0.366
Class satisfaction	4.60	0.53	4.56	0.55	-0.391	0.697

***P<0.001; tested by independent t-test
CPR, cardiopulmonary resuscitation; SD, standard deviation

Discussion

This study explored the new educational methods for improving the emergency care capabilities of firefighters in the field. Medi-VR simulation has already been actively used in medical education and clinical courses with various strategies (13-14). However, in the Korea, commercial programs using medi-VR simulation at the prehospital stage are still in their infancy, and there have been few cases of its use and application in the prehospital field (15-16).

In our study, the mean post-education CPR performance knowledge and self-efficacy scores in the medi-VR simulation group were significantly higher than the pre-education scores. Jung et al.

(15) also showed higher educational interest scores and CPR skill scores in a medi-VR education intervention group compared with a flipped learning group. Additionally, although the scores for knowledge, satisfaction, and achievements increased, they were not significant. In a study by Treat et al. (17), 96% of the students reported that their knowledge of the use of defibrillators improved after defibrillator training using VR. Hubali et al. (3) also reported that medi-VR chest compression-resuscitation training improved knowledge and confidence compared with traditional training; showing that medi-VR training can be an alternative. Similarly, Farra et al. (18) showed the significant effect of medi-VR in disaster training for a patient triage system (simple triage and rapid treatment) and radiation infections. Thus, medi-VR training for patients in disasters and accidents can have positive effects.

The mean CPR performance knowledge score in the flipped learning group was significantly higher post-education than pre-education. Additionally, the post-education CPR self-efficacy score increased by 18.2% compared with the pre-education score, which was 8.2% higher than that reported by Lee and Eun (19). Another study reported that simulation-based flipped learning for CPR resulted in significantly higher satisfaction and skill scores than traditional education (5). Overall, as medi-VR simulation and flipped learning were shown to be effective methods for increasing CPR knowledge and self-efficacy, practice-oriented education that enables CPR training, instead of theory-oriented education, should be included in the curriculum.

Flipped learning-based intervention education among nursing students was effective for knowledge, attitude, and clinical practice immediately after intervention and even one month later compared with a conventional learning method (20). Moreover, after three months, the knowledge score was even higher, although the attitude score was lower than that in the conventional learning method. Medi-VR flipped learning based on an online platform, initiated during COVID-19 restrictions, resulted in a high level of knowledge satisfaction and confidence in in-class collaborative activities (93.55%) and discussions (96.77%) (21). Again, confirming flipped learning as a useful educational method that should be included in curriculums.

In our study, the post-education scores for CPR knowledge and performance were significantly higher for the medi-VR simulation group than those in the flipped learning group. However, there were no significant differences between the groups for self-efficacy, class immersion, and class satisfaction. Yet, both groups did show considerable positive effects on learning. Leary et al. (22) showed that a medi-VR CPR education mobile app resulted in significantly higher scores for calling 911 (contact the emergency services) (82% vs. 58%) and asking for an AED (57% vs. 28%) than those from a conventional CPR education mobile app; however, there was no significant difference regarding CPR performance, such as chest compression rate (104±42 vs. 112±30 compressions per minute) and depth (38±15 vs. 44±13 cm), or application of the AED. Another study showed that CPR training using medi-VR simulation resulted in no difference in compression depth compared with face-to-face training but did show a lower compression rate (23). Overall, we should not disregard the fact that medi-VR education may show a difference in actual performance practice due to a lack of training in real situations.

In sum, our study and previous ones (3,5,20-22) show that medi-VR simulation and flipped learning can be used as effective interventional education for emergency care for cardiac arrest in the prehospital field. In particular, this study found that the medi-VR simulation method was superior to flipped learning in CPR performance. However, we need to remember that medi-VR remains in its early stages with more content development needed. Additionally, the system is more expensive than a conventional simulation system regarding set up cost for an educational environment.

Our study did confirm that learning with heightened realism using these two teaching methods can help participants resolve emergency care problems in a prehospital setting and enhance their ability to respond to emergencies. Thus, these two teaching methods should be further developed to complement the limitations of the respective methods, such as the absence of real on-site training. Flipped learning requires a more detailed curriculum and application so that students can strengthen their problem-solving abilities; while medi-VR simulation requires the development of additional content application in the field. Furthermore, future research should focus on understanding the differences in the course of practice and types of learning when using online lectures and prehospital field teaching methods.

Ultimately, several limitations of our study warrant comment. First, although we included data for 128 firefighters, our results may not be generalizable to all Korean firefighters. Second, the study did not include a no-treatment group. We only analyzed the differences between the pre- and post-education stages. In future studies, well-designed randomized controlled trials should be considered. Third, as our sample included only a small number of women, further studies are necessary that increase the sample size and identify whether there are any gender-based differences in these learning methods. Fourth, since this was a quasi-experimental design study based on acute time, a longer-term investigation is needed.

Conclusion

We were able to verify the medi-VR simulation and flipped learning methods as effective educational intervention training that results in high-class immersion and satisfaction for emergency care education for cardiac arrest cases in the prehospital field. Moreover, the medi-VR method showed a significantly higher CPR performance than the flipped learning method. Considering the future of firefighter education in the prehospital field, the application of education methods should consider cost, time, and space. Going forward, we need to study the continuous effect of CPR techniques after training. Additionally, implementing self-directed education methods, such as medi-VR simulation, should be explored further.

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Declaration Statement

The authors declare no conflicts of interest.

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